Studying eating habits in the vicinity of French nuclear power plants and dosimetric sensitivity due to ingestion after an accident

V. Parache[1], S. Roussel-Debet[1] and P. Renaud[1]

[1]IRSN, Laboratory for Continental and Mediterranean Radioecological Studies, CEN Cadarache, 13115 Saint Paul lès Durance, France

Abstract. Ingestion of potentially contaminated foods is the principal threat to consider in protecting the public living in the vicinity of a nuclear plant, whether in times of normal operation or in the event of an accident. In post-accident situations, the dietary parameters to be most carefully determined are consumption of foods that are most vulnerable to radioactive contamination, particularly the different types of vegetables and dairy products, the proportion of foods produced locally (near the accident site), and the delay between their production and consumption, so as to account for the radioactive decay curve. The summarized results of these three studies have enabled validation of a robust, reproducible protocol and confirmed the pertinence of the local scale by highlighting

eating habits that might enhance risks of exposure for some population groups. In particular, rates of home consumption vary from one food category to another and are sometimes high: over 90% for the most vulnerable products. Conducting a survey around each of the sites would therefore significantly improve both the quality of dosimetric assessments and their credibility in the public eye.

1. INTRODUCTION

To assess the impact on the population following ingestion of foodstuffs potentially contaminated in the vicinity of an industrial facility, data regarding the dietary practices of the local inhabitants are required, especially data on the proportion of foodstuffs produced locally. Currently, the available data regarding home-consumption rates among the French population are based on national statistics that are partially out-of-date, and which limit this notion to the consumption of exclusively privately produced food [1, 2]. Moreover, a national survey aims to give a comprehensive overview representative of the entire population's food habits, whereas, in the case of a survey carried out to define the parameters of an impact study, the aim is to identify the habits of people potentially most at risk of exposure. To counter these limitations, a survey protocol of investigation on a local scale has been developed and tested in three recent studies

conducted by IRSN around nuclear sites: Marcoule (Rhone Valley, 2010), Chinon-Avoine (Loire Valley, 2008) and Pierrelatte-Tricastin [1] (Rhone Valley, 2004-2005). The prime objective was to describe eating habits that could raise risks of exposure for the population, particularly consumption of foods produced near an industrial site and likely to be contaminated either by authorized routine releases or after an accidental release. In situ, these surveys were conducted by the BEGEAT [3, 4, 5, 6 and 7].

2. FOOD SURVEY METHODOLOGY

2.1. Methodological background

In the case of national surveys and those designed especially for populations living near nuclear facilities, the method of consumer notebooks is usually chosen [8]. The contribution of national surveys is nevertheless insufficient. They provide, indeed, general data on the eating habits of the population (e.g., annual food consumption per person depending on the size of municipalities), but the specific behaviours of those potentially most at risk can not be identified and characterized only by these investigations. Analysis of this feedback has provided the framework for the protocol proposed here.

---

[1] The study was funded by the ADEME (Contract No. 0772C0064).

The methodology of the surveys conducted was based on several surveys previously carried out in the vicinity of nuclear sites. In 2004, in partnership with AREVA and BEGEAT, the French Institute for Radioprotection and Nuclear Safety studied eating habits among the residents of Bollène, living near the Tricastin nuclear power plant (Rhone Valley), so as to better quantify the potential health impacts of the nuclear installations. On the basis of these studies, in the framework of the SENSIB project which aims at characterizing the vulnerability due to the nuclear risk, a survey protocol was developed and tested, during the summer 2008, around the Chinon nuclear plant, in collaboration with EDF, and is currently tested around the Marcoule nuclear plant, in collaboration with CEA. The aim was to optimize the feasibility and the reproducibility of the approach, while losing none of the robustness of the results.

Food habits are a determining factor in assessing doses due to the ingestion of contaminated foodstuffs produced locally. Home-consumption is defined as the consumption of foodstuffs produced or picked by the consumer and of foodstuffs from local sources. Seasonal variations play a major role in the consumption of foodstuffs from local sources. Carrying out surveys on local farm products and on their distribution chains is necessary to define

the food habits of populations more accurately. The consumption of fresh produce (vegetables and dairy products) as seasonal variations in production and consumption of these products must be taken into account.

2.2. Surveys around industrial sites

This study on developing a methodological approach and analysis is illustrated by three survey campaigns carried out in 2004-2005, in 2008 and 2010 respectively. An initial protocol was defined for the area near the Tricastin site, primarily to obtain information on the population's lifestyles and habits resulting in potentially higher levels of exposure: consumption of local produce or food produced at private sources, hunting and picking practices, etc. This resulted in focusing the objectives of the survey on the determining factors in the assessment of home-consumption rates. This protocol was then used in the survey on the Chinon site and on the Marcoule site, taking into account: (1) the informative nature of the results obtained for the first study, (2) national trends in the population's food habits and (3) the objective to ensure that the protocol could be reproduced in the future. This approach consisted of several stages:

• defining the population group to be surveyed and the area covered by the study;

• choosing the survey period and seasonal variations in home-consumption habits;
• providing information to the inhabitants surveyed and drawing up a survey questionnaire in the form of a weekly home-consumption notebook;
• the survey and statistical processing of the collected data.

The membership of families in the survey protocol is felt to be onerous (intelligence daily questionnaire) based on three essential elements: (1) information input given to families and the wider populations of commons surveyed on the subject of the study and its conduct, (2) the design of information collected, with tracking down the issue to which will discourage the respondent and lead to an unusable questionnaire and (3) the experience and human qualities of the investigator.

3. Results

3.1. Food ration (Figure 1)

In the study of Chinon, there is a high consumption of vegetables (44% of the diet, 536 g/d), including vegetables (nearly 19% of the solid diet, or 260 g/d), and fruits (average of 191 g/d). The place all meat, eggs and fish is also important insofar as it represents over 24% of the solid ration, an average of 296 g/d. The population surveyed near the Tricastin site has a high consumption of vegetables (40 to 45% of

solids intake) and fruits (15%). Meat, eggs and fish make up 18 to 24% of solids intake. The population living near the Chinon site also has a high consumption of vegetables (39% of solids intake) and fruits (15%). The population surveyed near the Marcoule site also has a high consumption of vegetables (524 g/d) and fruit (272 g/d) representing respectively 32% and 16.5% of solids intake. Consumption of meat, eggs and fish are similar to the one near the Tricastin site: 24% of Chinon solids intake and 17,5% of Marcoule solids intake.

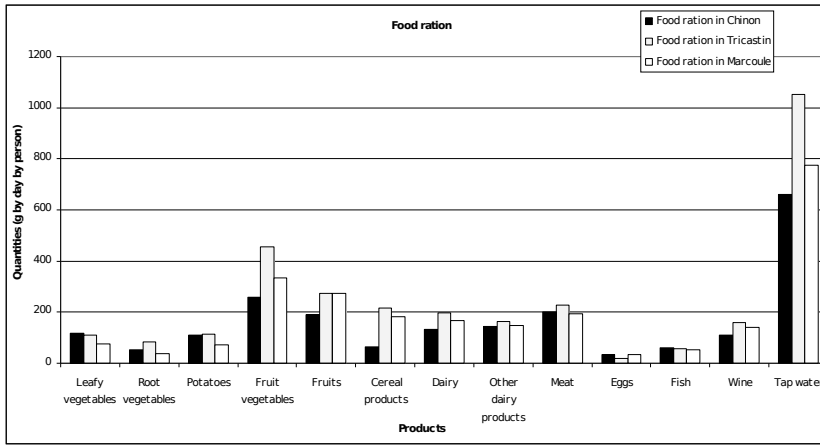


Figure 1: Foods intake (g/day.person) of populations living near the Chinon, Marcoule and Tricastin sites.

3.2. Home-consumption (Table 1)

In these studies, it was confirmed that target populations of the survey have high rates of home-consumption, of around 70 to over 90% for different food categories (see Table 1). For plant crops, the results are of the same order of magnitude at these sites, with the exception of fruiting vegetables and fruits, consumed and own-consumed in significantly larger quantities by the population surveyed at Tricastin. On the other hand, home-consumption rates are higher in Chinon in the case of meat, eggs and especially dairy products. The population surveyed near the Marcoule site averages between those of Tricastin and that of Chinon. This finding can be compared with local production in each of the two regions [4, 5 and 6]. In both cases, apart from the "region of origin" effect, rates of home-consumption also vary from one food category to another.

Products	Home-consumption rate (%) in Chinon (Loire Valley)	Home-consumption rate (%) in Tricastin (Rhone Valley)	Home-consumption rate (%) in Marcoule (Rhone Valley)
Leafy vegetables	85,8	89,8	75,5
Root vegetables	79,7	84,6	65,8
Potatoes	92,8	89,8	80,4
Fruit vegetables	87,9	92,1	87,0
Fruits	41,8	81,6	74,1
Cereal products	0,0	0,0	0,0

Dairy	5,0	0,0	0,0
Other dairy products	0,3	0,0	0,8
Meat	27,0	24,8	13,0
Eggs	69,7	54,4	52,2
Fish	7,0	11,9	4,3
Wine	84,9	78,7	94,0
Tap water	2,0	0,0	7,0

Table 1: Home-consumption rates observed in the populations surveyed in the vicinity of nuclear sites (in percent of the total solid or liquid intake).

3.3. Dosimetric sensitivity due to ingestion (Figure 2)

The ingestion dose is proportional to the contamination of food consumed and to the amount of food ingested. Moreover, due to the existence of products much more sensitive to contamination (leafy vegetables, milk and dairy products, including goat and sheep), food habits are quickly becoming predominant over the importance of radioactive deposits around the same locality of residence.

So, doses from food ingestion depend on:

- locally sourced food within the diet of the population (degree of autarky, in the broadest sense). Food surveys conducted by IRSN around some nuclear sites show that the season can have a strong influence on the degree of autarky and, consequently,

the dose that would be received by some categories of population in case of accident;

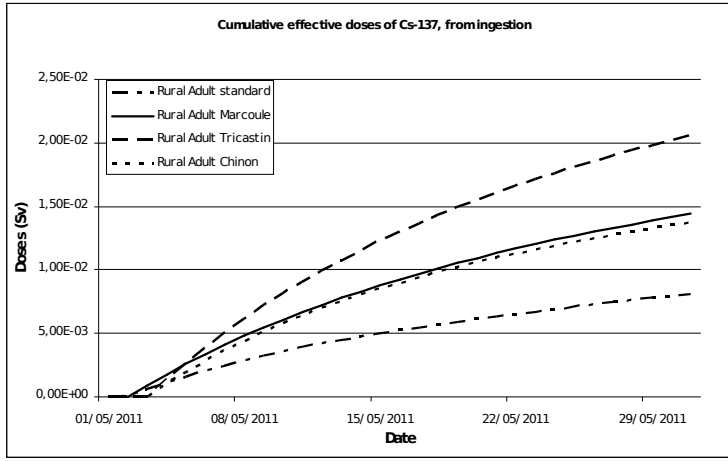
- the nature of the food produced locally, depending on location and season in which the accident occurs. Regarding the doses received during the first month after an atmospheric release, special attention should be paid to the proportion of consumption of fresh produce (leafy vegetables and dairy products) in the diet. Indeed, during this period, the contribution of other foods (meat, canned milk, soft cheeses, cereal products, game ...) is low and becomes significant later.

To assess dosimetric sensitivity due to different eating habits, we chose a site such as "theoretical." We vary only food rations and levels of consumption of people.

Eating habits are very different from the standard diet provided in the ASTRAL model of IRSN [9]; they contribute to modify the effective dose from ingestion for adults (see Figure 2). For example, the accident scenario considered is as follows: accidental discharge of a 1MBq of Iodine-131 and a 1MBq of Césium-137, 2011. Iodine-131 and Cesium-137 radionuclides are two typical among other accidental atmospheric releases from nuclear power plant. The date of deposit is also taken as an example (May 1, 2011).

The surveyed population near the Tricastin sites is more sensitive than those surveyed

around Chinon and Marcoule nuclear sites. Moreover, in the case of iodine contamination, the population of Chinon differs from that of Marcoule particularly because of its higher consumption of dairy products.



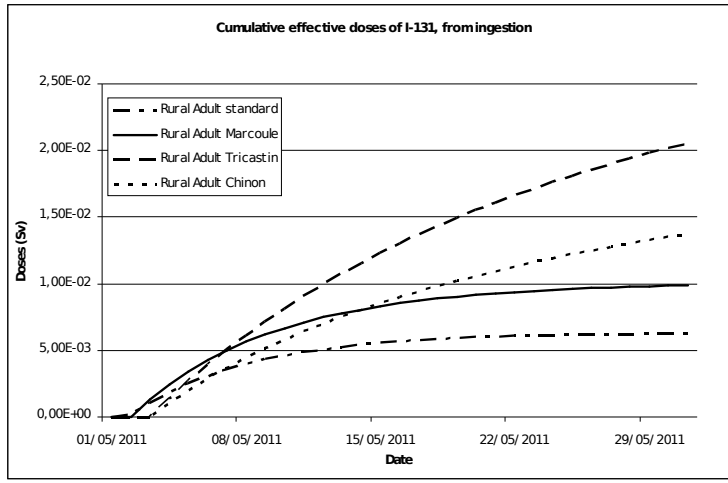


Figure 2: Cumulative effective doses to adult of iodine and cesium from ingestion

for the three studied rations compared with the standard ration of ASTRAL.

4. Conclusions

Current practice in health risk assessment for impact studies shows that in the absence of robust data acquired under reproducible conditions, the practitioner who wishes to introduce the concept of consumption in its exposure scenarios has most often the choice between two extremes: 100% or 0% of consumption, and this all food categories combined. Yet the results gained through this study confirm the variability of this important parameter of the sensitivity of a population exposed to discharges of industrial nuclear. Despite of changing eating habits (supermarkets, ready meals), there are still groups of people with high consumption practices whose variability is expressed on the one hand according to the categories of food and other unit based on the study area.

Food surveys near industrial sites provide a more precise understanding of the food habits of local residents. Taking into account local supply systems serves to further allow more realistic study compared with study performed only with national data. There are still population groups that have a high level of "home-consumption".

These preliminary results underscore the importance of helping the knowledge of some lifestyle-specific territories, particularly in the context of crisis. They reinforce the issues associated with the

continued implementation of this protocol in other regions (quarter Northeast and Southwest waterfront sites in France).

Furthermore, the CODIR PA[2] groups recommends that investigations are more interested in food consumption of leafy vegetables and fresh dairy products because of their immediate sensitivity to contamination by air pollution, and take into account seasonal variations in once on the consumption of these foods. Indeed, surveys currently available are not very informative on this subject. Given the variety of diets across France, it would be appropriate to conduct investigations locally, around nuclear sites. It is also proposed that investigations be conducted on local agricultural products themselves as well as their distribution channel.

5. ACKNOWLEDGEMENTS

The study in Chinon site is financially supported by ADEME (Agreement No. 0772C0064).

6. REFERENCES

[1] Institut National de la Statistique et des Etudes Economiques (INSEE).

[2] Comité Directeur pour la gestion de la phase Post-Accidentelle d'un accident nucléaire ou d'une situation d'urgence radiologique

Consommation et lieux d'achats des produits alimentaires en 1991, France.
[2] DUBEAUX D., 1994. Les Français ont la main verte, INSEE Première, n°338, août 1994.
[3] Durand V. and Mercat C. Comparaison des résultats de l'enquête alimentaire de Pierrelatte-Tricastin avec d'autres enquêtes françaises – SENSIB Project. IRSN/DEI/SESURE Report No.2007-45, 2007.
[4] Parache V., Résultats de l'enquête alimentaire autour du site nucléaire du Tricastin (2004-2005). IRSN/DEI/SESURE Report No. 2010-31, 2010.
[5] Parache V., SENSIB Project - Enquête alimentaire autour du site nucléaire de Chinon-Avoine : résultats et comparaison avec des enquêtes précédentes. IRSN/DEI/SESURE Report No. 2009-24, 2009.
[6] Parache V., SENSIB Project – Enquête alimentaire autour du site nucléaire du CEA de Marcoule : méthodologie et résultats. IRSN/DEI/SESURE Report No. 2011-07, 2011.
[7] Parache V., Maurau S. and MERCAT C., Food surveys for assessing health risks near industrial sites: methodology and main results near two nuclear sites. Environnement Risques et Santé, *sous presse*.
[8] Durand V., Vray F. and Mercat C. Improving the knowledge of exposure by

ingestion thanks to food surveys. International ISEE/ISEA Conference, Paris, 2-8 September 2006.
[9] Mourlon C. and Calmon P. 2006. Equations et paramètres du logiciel ASTRAL V2.3- Rapport IRSN/DEI/SECRE n° 06-47.